<u>Total sum of squares (SSTo)</u> - A measure of the total amount of variation in observed y values.

<u>Coefficient of determination (r^2)</u> - The proportion of total variation in y that can be attributed to an approximate linear relationship; $r^2 = 1 - \text{SSResid/SSTo}$.

<u>Standard deviation about the least squares line (s_e)</u> - The typical amount by which an (x, y) point deviates from the least squares line, given by

$$s_e = \sqrt{\text{SS Resid}/(n-2)}$$

<u>Power transformation</u> - An exponent, or power, p is first specified, and then new (transformed) data values are calculated as *transformed value* = (original value)^p. A logarithmic transformation is identified with $p = 0$. When the scatter plot of original data exhibits curvature, a power transformation of x and/or y will often result in a scatter plot that has a linear appearance.

<u>Standardized residual</u> - A residual divided by its estimated standard deviation.

<u>Standardized residual plot</u> - A plot of (x, standardized residual) pairs that is useful for checking the appropriateness of the fitted model and identifying any unusual observations.

3.0 SAMPLING TRAINS AND ANALYTICAL PROCEDURES

3.1 Description of Sampling and Analytical Procedures

The most critical gaseous constituents to be measured are carbon monoxide, excess oxygen, and nitric oxide. Carbon monoxide emission trends are a positive indicator of incomplete combustion. The excess oxygen distribution is utilized to determine both burner performance and to indicate staging distribution. It is a direct indicator of NO_x formation. Nitric oxide is formed in the peak flame temperature regions and is an excellent indicator of flame intensity and changes in the local interaction between burner aerodynamics and fuel dynamics. Carbon dioxide readings are taken and used as an analytical and quality control check of the O_2 instrument.

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3.1.1 Oxygen

Oxygen will be measured in accordance with EPA Method 3A. This method utilizes continuous emissions monitoring instrumentation. Sampling will be conducted using a Teledyne Model 320 fuel cell type monitor with ranges to 5 percent, 10 percent, and full scale of 25 percent. The instrument meets all of the performance specifications of the method. It will be calibrated before and after each test period using calibration gases prepared according to EPA Protocol #1. See instrumentation specifications below. In addition, all pertinent calibration data sheets will be incorporated in the final report. Sampling for O_2 will be made at the normal unit emissions test port.

O_2 Analyzer

Make:	Teledyne Model 320 - fuel cell
Precision:	1% of full scale
Response:	90% in less than 40 seconds
Sensitivity:	1% of low range
Linearity:	1% of full scale
Ambient Temperature Range:	32 - 125°F
Output:	4-20 mA
Ranges:	5%, 10%; full scale of 25%
Calibration Gases:	Protocol #1

3.1.2 Carbon Monoxide

Carbon monoxide will be measured in accordance with EPA Method 10. This method utilizes continuous emissions monitoring instrumentation. ESA will use an Energetic Sciences Model 2000 monitor with ranges from 0-2500 ppm. The instrument meets all of the performance specifications of EPA Method 10. It will be calibrated before and after each test period using calibration gases prepared according to EPA

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Protocol #1. See below for the instrument specifications. In addition, all pertinent calibration data sheets will be included in the final report. Sampling for carbon monoxide will be made at the normal unit emissions test port.

CO Analyzer

Make:	Energetic Sciences Model 2000
Precision:	1% of full scale
Span Stability:	1% of full scale in 24 hours
Zero Stability:	1% of full scale in 24 hours
Response:	90% of full scale in 2.5 seconds
Sensitivity:	1% of low rage
Linearity:	1% of full scale
Ambient Temperature Range:	32 - 120°F
Output:	4-20 mA
Ranges:	500, full scale of 2500 ppm
Calibration Gases:	Protocol #1

3.1.3 Oxides of Nitrogen

Oxides of nitrogen will be measured in accordance with EPA Method 7E. This method utilizes continuous emissions monitoring instrumentation. ESA will use a Thermo Electron (TECO) Model 10 AR NO_x chemiluminescent monitor with eight ranges from 0-10,000 ppm. The instrument meets all of the performance specifications of the method. It will be calibrated before and after each test period using calibration gases prepared according to EPA Protocol #1. See below for the instrument specifications. In addition, all pertinent calibration data sheets will be included in the final report. Sampling for oxides of nitrogen will be made at the normal unit emissions test port.

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<u>NO$_x$ Analyzer</u>

Make:	TECO Model 10 - Chemiluminescent
Span Stability:	1% of full scale in 24 hours
Zero Stability:	1% of full scale in 24 hours
Response:	90% of full scale in 1 second
Sensitivity:	0.5 ppm
Linearity:	1% of full scale
Output:	4-20 mA
Ranges:	2.5, 10, 25, 100, 250, 1000, 2500; full scale of 10,000 ppm
Calibration Gases:	Protocol #1

3.1.4 Carbon Dioxide

CO_2 will be measured in accordance with EPA Method 3A. This method utilizes continuous emissions monitoring instrumentation. ESA will use an Anarad Model 411 NDI type monitor with 20% as full scale range. The instrument meets all of the performance specifications of the method. It will be calibrated before and after each test period using calibration gases prepared according to EPA Protocol #1. See below for the instrument specifications. In addition, all pertinent calibration data sheets will be included in the final report. Sampling for carbon dioxide will be made at the normal unit emissions test port.

<u>CO$_2$ Analyzer</u>

Make:	Anarad Model 411 - non-dispersive infrared
Range:	Full scale of 20%
Calibration Gases:	Protocol #1

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3.1.5 Gas Density Determination

Gas density shall be determined in accordance with EPA Method 3A.

3.1.6 Correction to Three Percent O_2

All test results shall be corrected to three percent O_2.

3.2 Gas Composition Analysis

3.2.1 Sampling Apparatus

Flue gas samples are drawn from the flueway breechings through stainless steel probes. A sintered metal filter will be attached to each probe to prevent particulate matter from entering the gas stream. Immediately upon exiting the breeching, moisture is removed from the flue gas using an ice- and salt-cooled drop out system which effectively flash freezes water vapor from the sample before the gas stream has time to cool and condense. This cold knock out system is used until it has been demonstrated that the NO_2 is less than 5% of the total NO_x. The samples then pass through secondary gas filters and then enter a remote solenoid control valve; out of the control valve the sample flows at approximately 10 SCFM through a 3/8-inch Teflon tubing until it reaches the portable combustion lab. At this point in the system, the gas sample passes through a chiller and then through the sample pump. Out of the pump, the gas passed through the total sample flow controller and then to a series of five-way manifold valves and then flows through the individual instrument flow controllers and then enters the instrument. The instrument response is displayed on the front panel meters and is

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recorded by a multi-input Yokogawa recorder. A schematic of the equipment used to draw and process the sample flue gas is shown in Figure 6-1.

3.2.2 Gaseous Sampling Procedure

As required, a gaseous traverse will consist of the following measurements:

A. Perform a pre-test calibration error check and record the results on the gaseous data sheet.

B. Measure and record the concentration of O_2, NO_x, CO and CO_2 for flue matrix point. Insure that at least twice the system response time has elapsed before recording any gaseous data.

C. Perform a post-test calibration error check and record the results on the gaseous traverse data sheet.

3.2.3 Quality Assurance Check of the Sampling System for Interference by Moisture

The gaseous emissions of NO_x, O_2, CO and CO_2 will be sampled through unheated tubing. In order to demonstrate that this procedure does not create inaccuracy in the NO_x measurements, the following procedure will be used.

Document that the concentration of NO_2, < 5%. (This procedure to be conducted on the first day of testing on each unit.)

1. Sample emissions through dry sample lines (flash freeze system in place).

2. Measure both NO and NO_x emissions using the gaseous test sample point.

3. Verify the concentration of NO_2, expressed as $(NO_x-NO)/NO_x \times 100 < 5\%$.
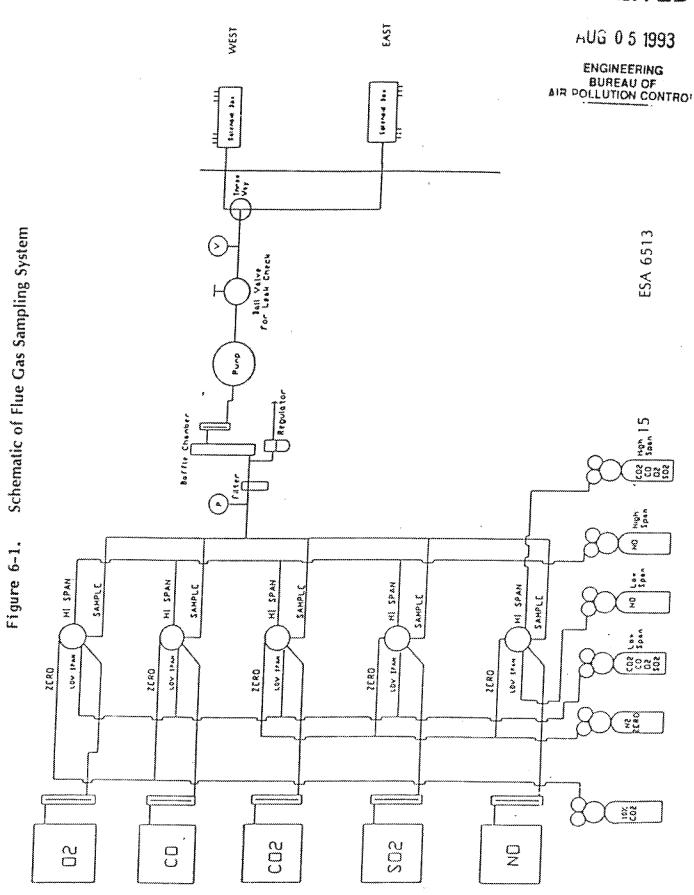
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Figure 6-1.   Schematic of Flue Gas Sampling System

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WEST

EAST

Bypass Vent

Ball Valve
For Leak Check

Pump

Baffle Chamber

Regulator

Filter

O2

CO

CO2

SO2

NO

HI SPAN

SAMPLE

ZERO

LOW SPAN

CO2 High Span 15
CO
O2
SO2

NO High Span

NO Low Span

CO2 Low Span
CO
O2
SO2

N2 ZERO

10% CO2

3.3 Description of Flue Gas Sampling

What follows is a description of the transportable continuous emissions sampling system that will be used to quantify the oxides of nitrogen emissions from the facility. The system will meet all the specifications of Reference Methods 3A (O_2/CO_2), 7E (NO_x) and 10 (CO).

3.3.1 Flue Gas Sampling System

Sample Probe - A heated stainless steel probe of sufficient length to allow a stack traverse during sampling.

Sample Line - 3/8" Teflon tubing (1/16" wall) to transport the sample gas from the probe to the sample conditioning system.

Sample Conditioning System -

Filter - A sintered metal filter located at the probe tip, to remove particulates from the gas stream.

Condenser (2) - An ice/saltwater cooled condenser (freeze-out system) located near the probe and an ice-cooled condenser system downstream from the pump.

Sample Pump - A diaphragm type vacuum pump to draw gas from the probe through the conditioning system and to the analyzers. The pump head is stainless steel, the valve disks are Viton and the diaphragm is Teflon coated.

Calibration Valve - A three way ball valve, located at the base of the probe, will allow the operator to select either the sample stream or a calibration gas stream.

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<u>Sample Distribution System</u> - A series of flow meters, valves, and back-pressure regulators will allow the operator to maintain constant flow and pressure conditions during sampling and calibration.

<u>Gas Analyzers</u> - capable of the continuous determination of O_2, CO_2, CO and NO_x concentrations in a sample gas stream. They will each meet or exceed the following specifications:

Calibration Error - Less than $\pm 2\%$ of span for the zero, mid-, and hi-range calibration gases.

System Bias - Less than $\pm 5\%$ of span for the zero, mid-, or hi-range calibration gases.

Zero Drift - Less than $\pm 3\%$ of span over the period of each test run (1 hour)

Calibration Drift - Less than $\pm 3\%$ of span over the period of each test run (1 hour).

3.3.2 Flue Gas Sampling Procedures

All sampling and analytical procedures will be conducted in accordance with EPA Reference Methods 3A, 7E and 10 (40 CFR 60, Appendix A). The following is the sequence of events leading up to and including the compliance test:

<u>Selection of Sampling Point Locations</u> - Sampling point locations will be determined prior to testing in accordance with EPA Methods 1, 3A, 7E, 10 and 6C.

<u>Determination of System Response Time</u> - System response time will be determined prior to testing. System response time will be determined according to procedures delineated in Performance Specification 2 (40 CFR 60, Appendix B).

<u>Determination of Analyzer Calibration Error</u> - Analyzer calibration error will be determined just prior to testing in accordance with EPA Methods 3A, 7E and 10.

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<u>Determination of Sampling System Bias</u> - Sampling system bias will be determined just prior to testing in accordance with EPA Methods 3A, 7E and 10.

<u>Determination of Zero and Calibration Drift</u> - Before and after each test run, each analyzer's response to zero and hi-range calibration gases will be determined. The pre- and post-test analyzer response will be compared to determine drift. The results will be evaluated based upon specifications defined in EPA Methods 3A, 7E, and 10.

<u>Data Reduction</u> - An average pollutant/diluent concentration for each test run will be determined from the data collected. This data will be reduced to determine relative pollutant concentrations (ppm corrected to three percent O_2) and emission rate (lb/10^6 Btu).

<u>NO$_2$ to NO Converter Efficiency</u>

The chemiluminescent NO_x analyzer to be used in the field must undergo an NO_2 to NO converter efficiency test prior to its initial use in field. This test is routinely performed on all NO_x analyzers at six-month intervals by qualified technicians. (Reference: Section 6.4 of EPA Method 7E.)

<u>Interference Gas Response Check</u>

The chemiluminescent NO_x analyzer must also undergo an interference gas response check prior to its initial use in the field. This test is routinely performed at one-year intervals or as usage dictates by qualified technicians. (Reference: Section 6.2, Method 7E and Section 5.4, Method 20.)

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3.4. NO$_x$ Trends/Flame Intensity

The nitric oxide concentrations will be measured. Nitric oxide is formed in the peak flame temperature regions; therefore, it is an excellent indicator of flame zone intensity and changes in the localized interaction between fuel dynamics and burner aerodynamics. There are many parameters which can impact the NO levels from a given boiler, including fuel surface area (particle size distribution, local aerodynamic swirl characteristics, fuel jet penetration, residence time, fuel bound nitrogen content, primary furnace slagging characteristics (heat transfer to tube walls), overall boiler O$_2$ levels, and local air/fuel ratios.

3.5   Furnace Exit Gas Temperature (As required for coke oven analysis)

Furnace exit temperatures are to be measured using a high velocity thermocouple (HVT) probe.

3.6   Steam Conditions

Real time trend logs are used to monitor superheat and reheat steam temperatures and attemperation flows to ensure that design temperatures are within controllable ranges during test runs.

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3.7 Flames and Furnace Wall Observation

Both flame observations and real time monitoring of the primary furnace during the tests will be made. The visual information obtained is used in conjunction with measurements of combustion gas products ($CO/O_2/NO$), furnace exit gas temperatures (FEGT), and superheat/reheat/temperature attemperation to characterize the combustion performance and slagging/fouling characteristics of each unit.

4.0 QUALITY CONTROL PROCEDURES

Throughout all phases of the test program, including sampling, analysis and data reduction, personnel will adhere to strict quality control procedures. Sampling will be conducted by trained personnel with extensive experience in sampling oxides of nitrogen.

All sampling and analysis will be conducted in strict accordance with EPA test procedures. The quality control procedures found in the EPA Quality Assurance Handbook for Air Pollution Measurement Systems will be adhered to as well.

All chemical reagents used in sampling, recovery and analysis will be certified American Chemical Society grade (unless a higher purity is specified in the Method). Filters for particulate analysis will be desiccated and weighed to a constant weight before and after testing as specified in the EPA Quality Assurance Handbook. All filters will be identified numerically in labelled petri dishes which will be sealed and transported to and from the field in a secure desiccator.

ESA's entire equipment inventory is on a schedule of routine maintenance and calibration. This includes thermocouples, barometers, pitot tubes, and sampling nozzles. Thermocouples are calibrated as specified in the EPA Handbook against an NBS traceable mercury in glass thermometer.

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